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MEASUREMENT OF PISTON POSITION IN A DEFORMABLE PISTON GUN

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One of the more elusive parameters associated with the operation of light-gas deformable piston guns is the time history of the piston. According to the theory of operation of the guns, final performance is a fairly sensitive function of the velocity with which the piston approaches the tapered high-pressure coupling just ahead of the launch tube. The following sections describe a method of measurement which has been used with a caliber 50 light-gas gun by William Page, Robert Miller, and Jack Stephenson, all of the Supersonic Free Flight Branch at Ames Research Center, NASA.

The present installation consists of two ballistic-type strain-gage pressure cells mounted 3 feet apart, the second one 2-1/2 feet from the exit of the tapered coupling. Readout from the gages were made on Tektronix 535a oscilloscopes. Figure 1 shows the arrangement of the gun. Also shown is a sketch of the piston used.

In operation, the pressure cells record the pressure ahead of the piston until the piston seals off the opening to the cell. After passage of the piston, the cell records the pressure behind the piston. Figure 2 shows, for a typical run, the recordings of variations in pressure at the two gages. The conditions of the tests are listed below the pressure traces. Figure 3 is a time-distance plot of events in the pump tube. Sketches of the pressure records shown in figure 2 are indicated at their appropriate locations along the pump tube. The events are then traced directly from their effects on the pressure. The velocity of the piston and the various shock waves are noted on the figure.

There are a number of observations that can be deduced concerning the operation of the gun from this figure.

Foremost among these is the fact that the diaphragm separating the launch tube from the pump tube apparently ruptured before the piston even reached the tapered coupling section. The exact time of rupture was not measured but was deduced from the subsequent time history of the model in the range. Incidentally, an unsuccessful attempt was made to measure the time of rupture by means of insulated break wires at the diaphragm.

The pressure cycle in the pump tube is certainly not an ideal isentropic compression. The figure shows three clearly defined shock waves. By extrapolating backward in time it is evident that there are more waves present in the pump tube before the initiation of the pressure traces shown here. In any case, the pressure rise associated with these prior waves is probably too small to be shown on the trace, although in several runs a fourth wave in addition to the three shown here is discernible. Calculations based on the data for hydrogen given in AEDC TR 62-32 and the measured piston velocity predict the experimentally observed shock waves and the pressure jumps with fair accuracy.

At station 2 at the time of passage of the piston, the observed pressure is 2800 psi. The computed pressure at the same instant, based on an isentropic compression, is 2030 psi.

A strong reflected shock wave produced from the rapid deceleration of the piston is shown travelling back through the powder gases.

Continuing along the cycle of operation, the pressures at the two stations drop suddenly to nominally zero pressure a short time after the passage of the reflected shock in the powder gas. This can only be explained by assuming that the piston bounces back from the high-pressure coupling and re-covers the pressure cell ports. The high pressure gas momentarily trapped ahead of the piston accelerates the piston back and imparts a velocity to the piston. By the time the piston has gone past the pressure cell closest to the coupling, the pressure has been dumped through the open launch tube and is nominally zero. The piston then decelerates as a result of the pressure remaining in the pump tube that continues to act on the rear face and probably follows the curved path of distance versus time as shown on the diagram. The pressure traces were not of long enough duration to show the eventual return of the piston to its final position in the tapered coupling.

There has been visual evidence in the pump tube that the piston did in fact bounce back into the pump tube. In one case one of the petals of the diaphragm was found imbedded in the side of the piston. It had scored the inside of the pump tube a distance of 13 feet back from the diaphragm station.

In both gages there is a sudden onset of electrical noise in the signal between the time that the piston initially went by and the time of the strong reflected shock in the powder gas. This is probably caused by a shock wave in the steel of the pump tube itself as a result of the rapid deceleration of the piston at the end of its stroke.

These results are, in reality, quite encouraging. The performance of the gun in its present mode of operation has been marginally acceptable. There is, however, a large potential for improvement.

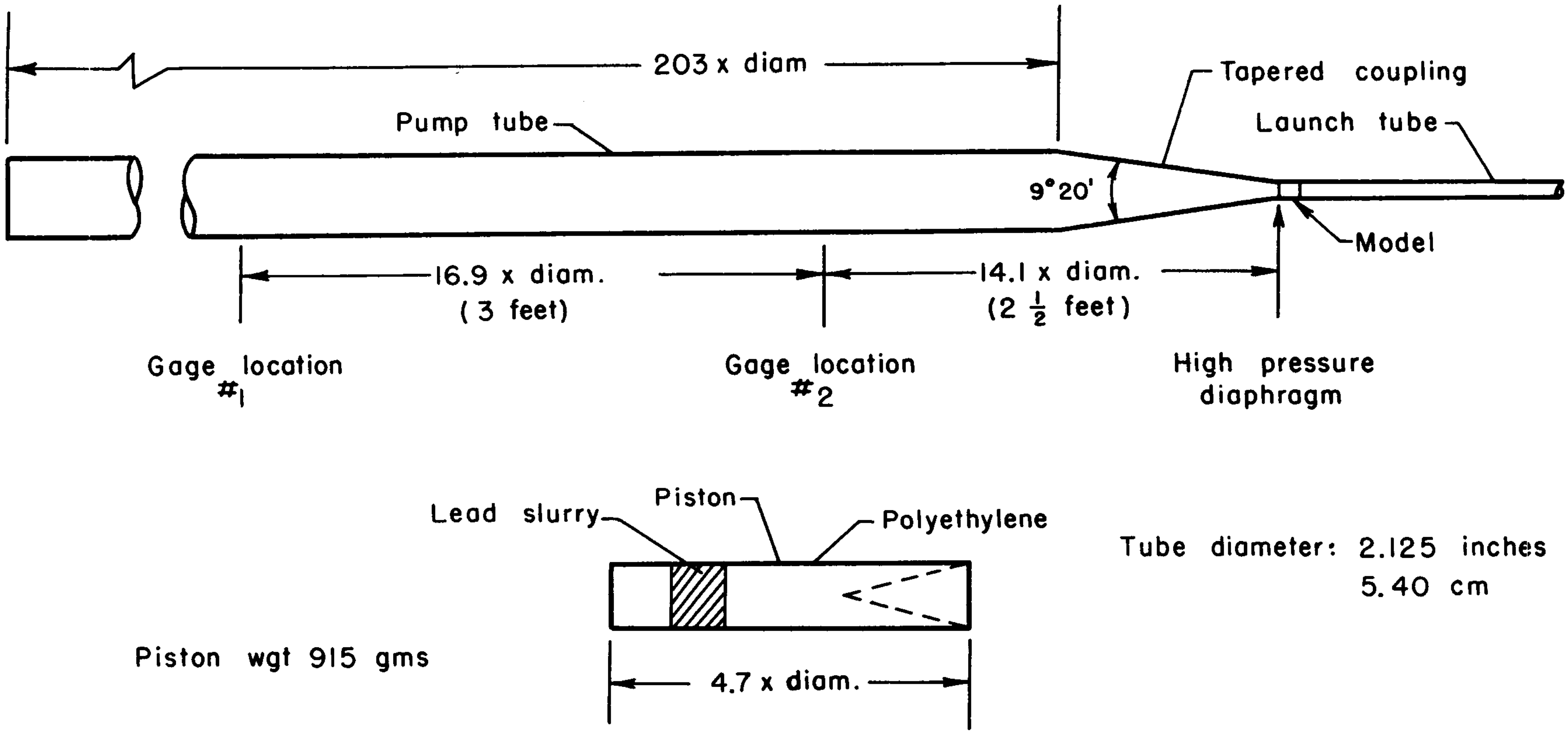

Figure 1.- Deformable piston gun.

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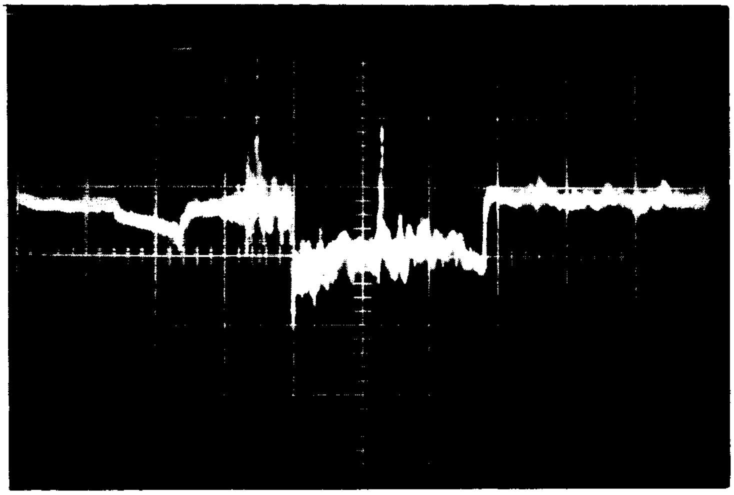
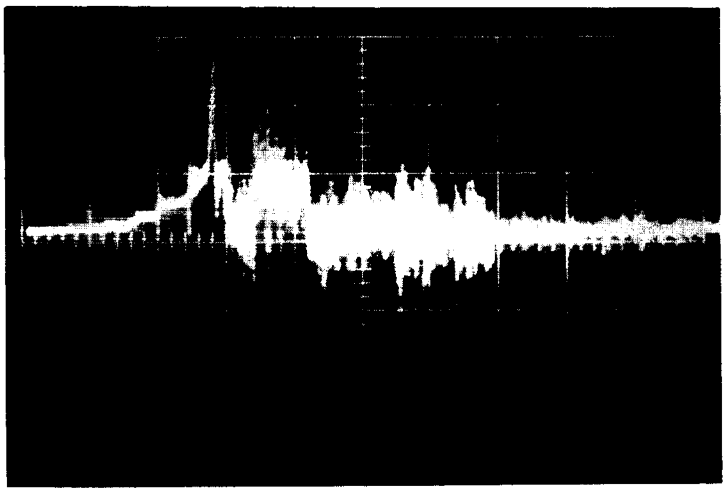


Gage position No. 1; 761 psi/cm; 2.60 milliseconds/cm



Gage position No. 2; 938 psi/cm; 2.60 milliseconds/cm

$P_{initial}$ = 35 psia; gas, hydrogen; powder, 170 gm 4198; piston weight, 915 gm; model velocity, 21,700 ft/sec

Figure 2.- Pressure-time traces.

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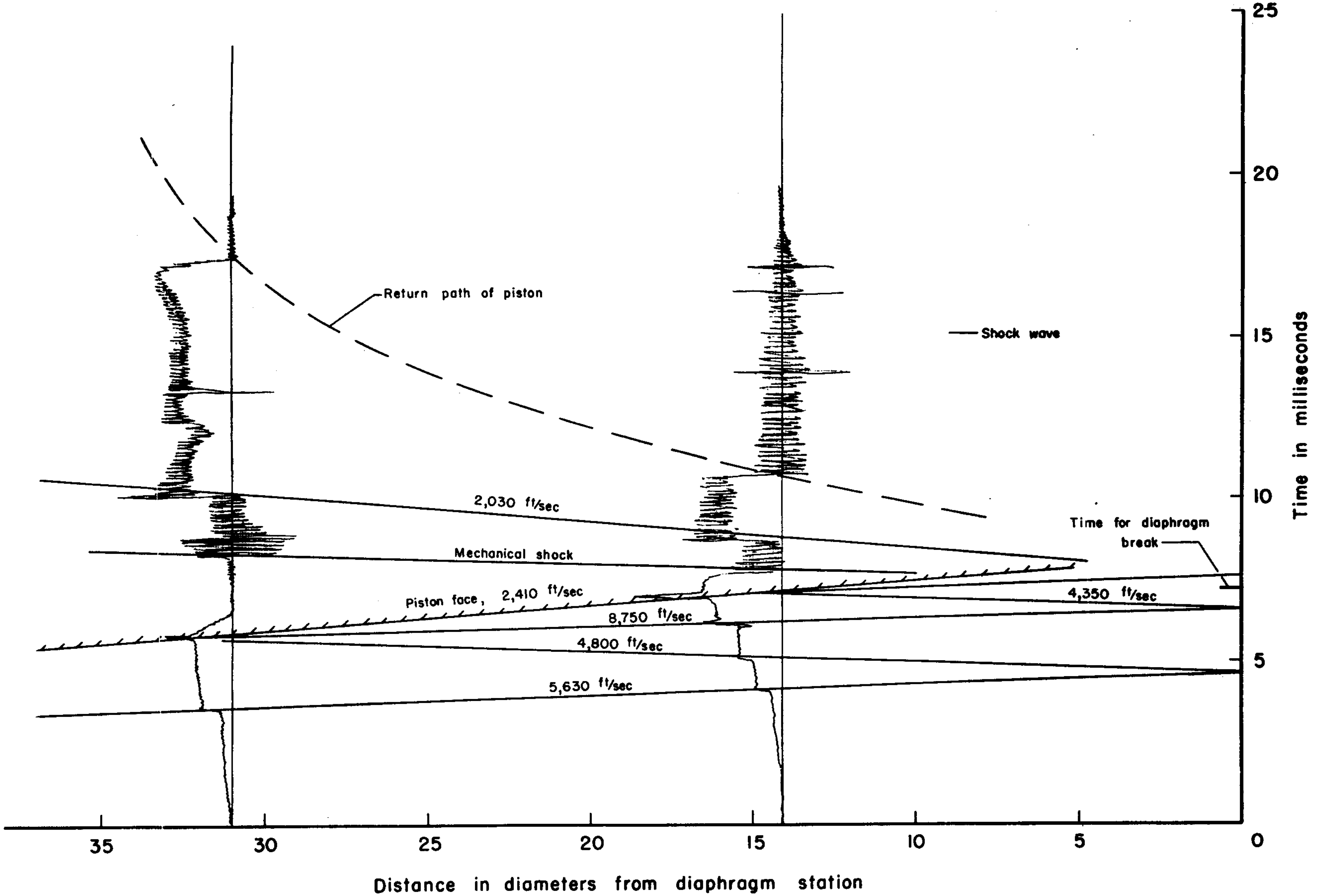

Figure 3.- Time history of events in pump tube.

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